TELKOMNIKA, Vol. 11, No. 6, June 2013, pp. 3391 ~ 3397
e-ISSN: 2087-278X

Research of ELCV 3D Localization Algorithm in Ship Area Networks

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Abstract

We propose a 3D localization algorithm used in ship area networks (SANs) in the literature before. In this paper in order to explore more performances of ELCV we made some other comprehensive simulations. In ELCV a classic noise model is introduced to characterize the acoustic background noise observed in SANs. Meanwhile random communication range nodes are placed in the SANs. ELCV is addressed to provide robust estimation of unknown nodes in the presence of outliers. In this algorithm sensor nodes are also equipped with random communication range that can be changed during a set scope. With ELCV, each individual unknown node will acquire data packages from anchors and then solve for a spatial node on some given point in cube space formed by eight neighbor anchors. With other three related anchor nodes around symmetric tetrahedron can be formed. Finally by centroid algorithm, in this symmetric tetrahedron, estimated node positions with accuracy and robustness are obtained. In this work more parameters are changed and different environment arguments are taken into account and then simulation results are given. By these simulation results we further prove the accuracy, efficiency and robustness in SANs. Meanwhile simulation processes are finished in MATLAB software.

Keywords: *ELCV, SANs, three dimensional, Localization Algorithm, Robustness*

1. Introduction

Recent fast technological advances have already enabled the development of low-cost, low-power and multifunctional sensor devices. In general, ship area networks intend to provide information on characteristics of the observed real physical world. Hence, the determination of the physical position of sensor nodes is a fundamental issue for many applications of wireless sensor networks. A number of applications, such as object tracking, environment monitoring, inherently rely on location information. Besides, location information is essential to many location-aware sensor network communication protocols, such as packet routing and sensing coverage. All these mentioned above make localization algorithm become one of the most important issues in WSNs researches. However, it has been a challenging task to design a practical algorithm for node localization given the constraints that are imposed on sensors, including limited power, low cost [1,2].

Considering the characteristics of cheap network nodes and the abundant deployment, the location algorithms need to satisfy the requirements of self-organization, robustness, energy efficiency, distributed computing, etc [3, 4, 5]. Many localization algorithms have been widely studied recently, a good survey of which can be found in [6] and [7], but there is yet lots of work to do in the field. Localization strategies vary by the capabilities of the nodes and environmental issues. Algorithms that try to locate nodes with raging capabilities are range-based and those that merely rely on the radio connectivity of the nodes are range-free algorithms.

Rage-based algorithms require extra hardware on nodes to make them capable of measuring distances, which would inevitably require more construction costs. Also, these measurements can be vulnerable to environmental issues, such as noise, temperature, humidity, et c. However, the fact is that, by providing proper algorithms and trade-offs, e.g. for

Received January 15, 2013; Revised April 18, 2013; Accepted April 27, 2013

node density, they can result in high localization accuracies, up to a few hundredth of the maximum radio range. Ranging is usually achieved by means of received- signal-strength (RSS), time-of-arrival (TOA), time-difference-of-arrival (TDOA), roundtrip-time-of-flight (RTOF), or angle-of-arrival (AOA); a good comparison of which can be found in [2] and [8, 9].

Rage-free algorithms, on the other hand, merely rely on the existence of radio connectivity to a neighbor instead of measuring distance to that. This means requiring less hardware, hence less expensive to implement. These approaches are independent of the amount of the ranging error and noise, which play an important role in range-based approaches. Yet, they are usually less accurate than range-based algorithms. These approaches like [8], [10], or [11], provide an estimate of each node position, which has been shown [11] that it is good enough for some applications like routing or tracking.

Based on the requirements listed above we proposed a kind of localization algorithm (ELCV) that suitable for wireless sensor networks in SAN on ship variable environment before. In ELCV a classic noise model is introduced to characterize the acoustic background noise observed in SANs. Meanwhile random communication range nodes are placed in the SANs. ELCV is addressed to provide robust estimation of unknown nodes in the presence of outliers. In this algorithm sensor nodes are also equipped with random communication range that can be changed during a set scope. With ELCV, each individual unknown node will acquire data packages from anchors and then solve for a spatial node on some given point in cube space formed by eight neighbor anchors. With other three related anchor nodes around symmetric tetrahedron can be formed. Finally by centroid algorithm, in this symmetric tetrahedron, estimated node positions with accuracy and robustness are obtained. In this work more parameters are changed and different environment arguments are taken into account and then simulation results are given. By these simulation results we further prove the accuracy, efficiency and robustness in SANs. Meanwhile simulation processes are finished in MATLAB software.

The rest of this paper is organized as follows. Section 2 gives the realization process of ELCV. Section 3 then mentions a significant simulation work and gives explicit simulation results. Next, conclusions are made in Section 4.

2. Realization Process of ELCV

2.1. General Gaussian Noise Model for Noise

Gaussian noise model is built to characterize and analyze the true nature of SANs. If there is no such a model whether this algorithm can be suitable for SANs environment could not be clear. The reasons that Gaussian noise model is adopted are as follows. First natural interference, such as wind gust, ship shake, thunder and hail storm are all potential sources for producing high intensity acoustic noise in the background. Second when the SNAs is deployed a hostile environments, sensors may be sabotaged and acoustic interferences may be imposed to badly compromise the performance of the SANs. In some severe conditions it may lead to system paralysis. Third equipment failures in individual sensor nodes may also manifest themselves as impulsive outlier background noise. So the use of a Gaussian distribution to model the acoustic energy of background noise will be needful and adequate to simulate ship situations.

In this work, assume that N sensors are randomly deployed in a large 3-D ship sensing space at known locations $\{l_i;1 \le i \le N\}$. At kth time instant, a source at location τ_k is emitting an acoustic signal with a constant energy level S (measured at 1-unit distance). At the ith sensor, the jth $(1 \le j \le M)$ energy of the received signal energy can be expressed as following equation:

$$\begin{cases} y_{i,j}(k) = f(x_i,\theta(k)) + e_{i,j} \\ f(x_i,\theta(k)) = \dfrac{g_i S}{\|L_I - \tau(k)\|^2} \end{cases} \tag{1}$$

A listed in equation (1), f is the energy of received source signal at the i th sensor, g_i is the sensor gain, and $\| \cdot \|$ is the Euclidian distance. In the above equations, $x_i = \{l_i, g_i\}$ are the known fixed parameters setting severe conditions of the deployed ith wireless sensor node and $\theta(k) = \{S, \tau_x(k), \tau_y(k)\}$ are unknown variables which may be estimated using MLE or nonlinear LS methods [18-20].

The additive measured noise which can be accurately expressed as $e_{i,j} \sim N(u_i,\sigma_i^2)$ is also assumed to be a wide sense stationary Gaussian random process whose mean value $u_i > 0$ and standard deviation σ_i can be estimated empirically from received data samples before.

Based on the analysis a general Gaussian model is presented as the form below:

$$F = G = N[f(x_i,\theta) + u_i, \sigma_i^2] \tag{2}$$

In equation (2), $G = N[f(x_i,\theta) + u_i, \sigma_i^2]$ can be seen as a Gaussian probability density function (PDF). Since signal energy is always non-negative, so in this situation one has $f(x_i,\theta) + u_i > \sigma_i > 0$. Note that G is identical with the attenuation model and also the Gaussian noise is in (1).

This model can be classified as a heavy-tail distribution and with other heavy tail distributions include the Cauchy distribution and the t-distribution.

2.2. Realization of ELCV Localization Algorithm

As shown in Fig.2, there are eight anchors which form a cube. Ai (i =1, 2… 8) is anchor node and V is the center of this cube.

Because anchor nodes always exist in our supposed WSNs, the center node (Node V in Fig.2) can also be found out. This node locates in the center of the special cube as well as the centroid. Of course, there is no sensor located on this point but is just virtualized in the sensing space to realize node self-localization in next step.

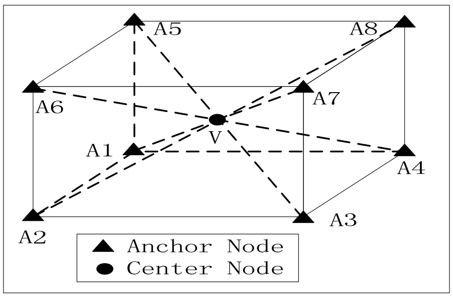


Figure 1. Model Building

From Fig.1 the center node divides the cube into four subspaces. Virtual central node and any other three anchor nodes can form a tetrahedron easily. Combining the anchor node information we can find out the decided tetrahedron in which unknown node locates. Then use the centroid of regular tetrahedron as the position of unknown node. Because the sensing space in which unknown node may locate is limited in a small tetrahedron, the estimated position error can be decreased to a low level.

In ELCV algorithm each sensor node estimates its position solely based on information gathered directly from surrounding anchor nodes. Since it does not depend on sensor node communication between neighbors, it is independent of network connectivity which is more suitable for being used on ship in ship area networks.

Now we will illustrate the ELCV algorithm in detail. First a random fixed time slice T is produced then the ELCV algorithm begins from flooding data packages from anchor nodes to the whole network. Each anchor node is able to broadcast information packages periodically. This time slice can also be set manually. The data information package includes anchor node ID, and coordinates of corresponding anchor nodes. Unknown nodes' communication function is easy and energy efficient because they are only in charge of listening to these packages from anchors in the presetting time slice T. Although each node has random communication rang once these data packages enter, it can detect and make recordings. Unknown nodes can memory how many packages have received from different anchors and record the amount of packages. There is lots of noise in it. By using general Gaussian noise model listed above the noise can be dealt with and further improve the accuracy.

Then they judge whether the time slice T is arrived. If so, the information can be recorded, or go on waiting. All unknown nodes can equally receive packages from all the anchors from the whole network and they only record the full information of three anchor nodes that have sent the most packages. Because three anchors that have sent most packages mean the most nearest to the unknown nodes. Choosing the three nearest anchors and general Gaussian noise model can effectively decrease localization error. That is because distance error can be accumulated from node to node. Once three anchors are recorded the next key step of ELCV localization algorithm is how to deduce the given space node.

After the three anchor nodes are assured, the center of the three can be computed easily using calculation of their coordinates as shown in Fig.2. It is on the same plane them. The difference between this center node and space node is that only one ordinate direction is different between the two and the other two ordinate directions are both the same. The coordinates of virtual central node can be obtained by changing one coordinate of center node. Combining Fig.1 and Fig.2 the changing one coordinate is adding or decreasing 10m in the sensing space to get coordinates.

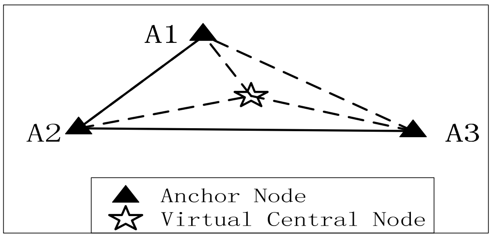


Figure 2. Computation in Proposed ELCV

In ELCV algorithm we don't need to compute a fourth node that is on the same plane with three anchors. In this way the computation time is diminished sharply and their localization accuracy is more or less the same.

The centroid of the four nodes (three anchors and space node) with determined position is used as the estimated coordinates of unknown nodes.

3. Research Method

3.1. Simulation Model Settings

Simulation work is accomplished under MATLAB simulation software. During the simulation process, the ship environment is supposed to be a three dimensional cube. All sensors are deployed in three dimensional environments. These sensors stand for different positions with different sensing mission on ship in Fig.1. The goal of ELCV is to find accurate coordinates of unknown nodes in this special 3D cube. The explicit model settings are as follows.

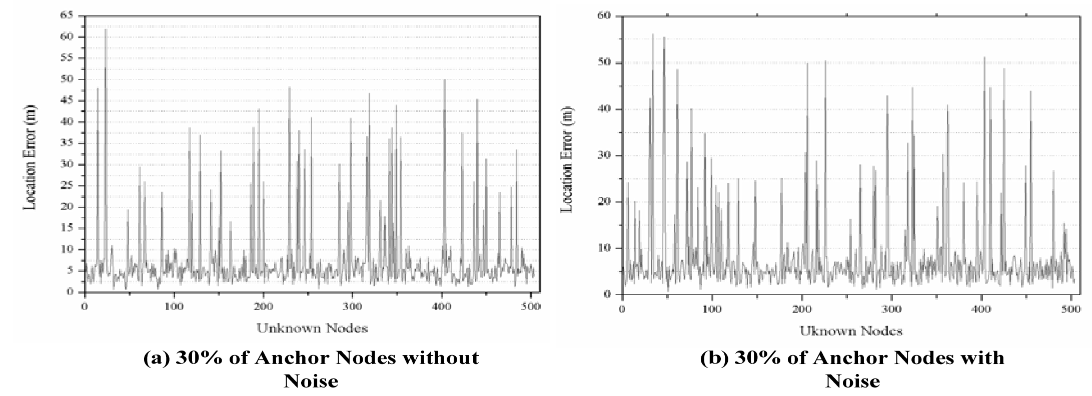
The localization space is supposed to be a 3D cube with the side length 100m. That is to say the whole volume of the 3D localization space is 100×100×100m3.

Unknown sensors are deployed randomly and their numbers can be changed artificially to simulate different ship environments in the sea environment. But anchors present a homogeneous distribution in this 3D space cube which leads to its total number will be fixed at 216. The communication range of each unknown node is a changeable parameter and changes randomly. Only in this way simulation condition could be infinitely close to real complicated ship situations and verify algorithm performances.

Anchor data package information from anchor nodes includes the signal intensity and source anchor's corresponding accurate coordinates. Also once the packages, which are sent by anchor nodes, enter the communication radius, unknown nodes can detect them and record the corresponding anchor information.

3.2. Analysis of Simulation Results

Figure 3 shows there are 500 unknown nodes in the network which means anchor nodes occupy 30% of all sensors. These unknowns are numbered from 1 to 500 under random communication range environments. Each sensor's error value is given in Figure 3. It is obvious when Gaussian noise is added there are more nodes becoming unstable. In Figure 3 (a) and (b) the biggest value is more or less the same which means the nodes cannot be localized. There are some nodes cannot be localized because of noise in the network. But in (a) most errors are below 5m and the other is above 5m. That is because Gaussian noise model is introduced and delete some effects from noise. The best value in (a) is 0.1m which is much smaller than the value in (b).



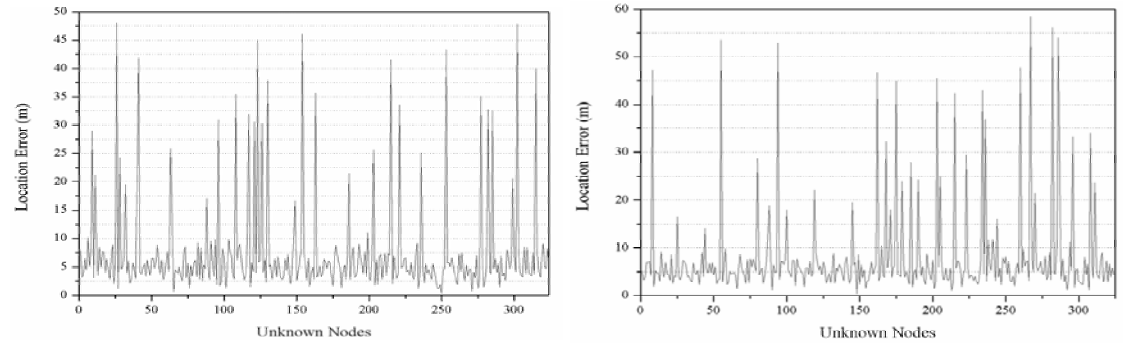
(a) 30% of Anchor Nodes without Noise

(b) 30% of Anchor Nodes with Noise

Figure 3. Position Error of Each Unknown Node (30% of anchors)

Figure 3 shows there are 325 unknown nodes in the network which means anchor nodes occupy 40% of all sensors. These unknowns are numbered from 1 to 325 under random communication range environments. Each sensor's error value is given in Figure 4 which gives similar results as in Figure 3 As percentage of anchors increase errors give download trend. From Figure 4 (a) and (b) we can find the two have nearly performances by Gaussian noise model. That is to say noise has few effects on our algorithm.

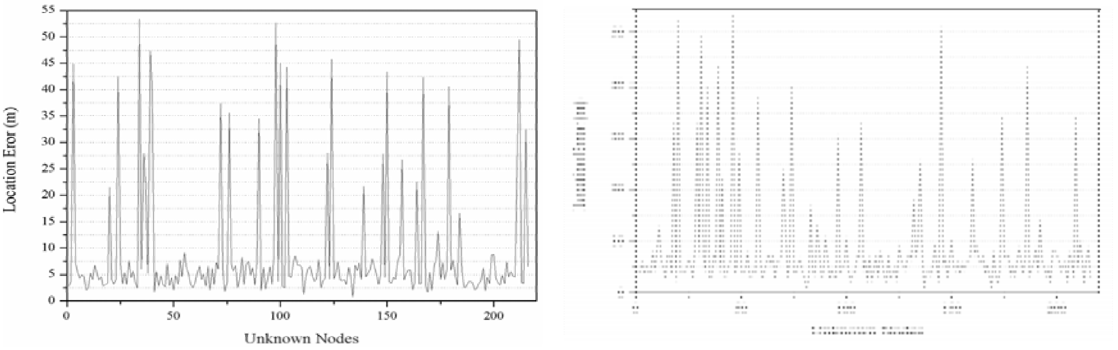
Figure 5 and Figure 6 shows the algorithm performances when percentage of anchors is set as 50% and 60% respectively. As number of anchors increases the distance between estimated and real position is getting smaller and smaller. In some extreme situations the error between them can be ignored. In the two figures noise in the network areas has so few effects on algorithm itself. For most nodes they can realize accurate localization. The impact of random communication range on the performance of ELCV is also investigated. In the four figures the performance of ELCV is independent on random communication range. That means it can overcome the communication range's bad effects which enlarge the application fields. It is suitable for complicated ship areas and other environment with obstructions in it.



(a) 40% of Anchor Nodes without Noise

(b) 40% of Anchor Nodes with Noise

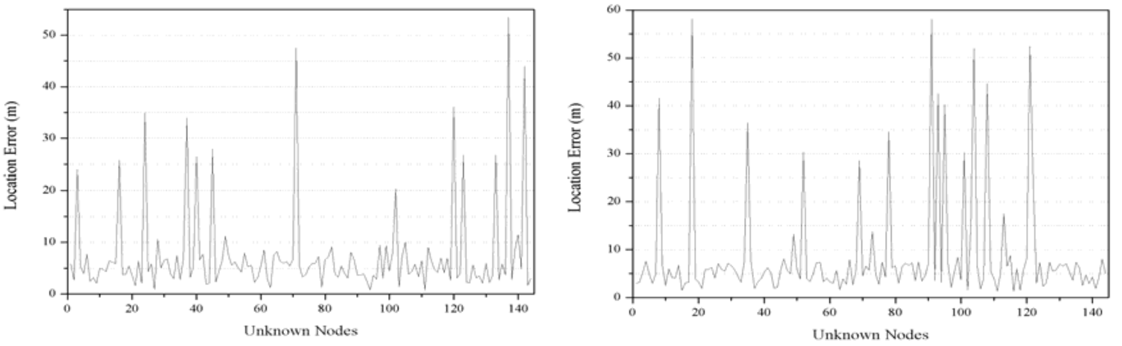
Figure 4. Position Error of Each Unknown Node (40% of anchors)



(a) 50% of Anchor Nodes without Noise

(b) 50% of Anchor Nodes with Noise

Figure 5. Position Error of Each Unknown Node (50% of anchors)



(a) 60% of Anchor Nodes without Noise

(b) 60% of Anchor Nodes with Noise

Figure 6. Position Error of Each Unknown Node (60% of anchors)

4. Conclusion

In this paper a high efficient localization algorithm that can be used in complicated vile 3D ship area networks (SANs), which is called ELCV is comprehensively analyzed. Simulation results validate the superior efficiency and robustness of these proposed algorithm compared to traditional ones. The simulation results tell that the localization accuracy has reached the best goal. And this algorithm can be widely used in different complicated environments. Future works may include robust target detection and tracking methods for outliers in SANs.

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